HYCOM Initial and Boundary Conditions for Coupled COAMPS/NCOM

Julie Pullen
Naval Research Laboratory
7 Grace Hopper Ave. Stop 2
Monterey, CA 93943
phone: (831-656-4645) fax: (831-656-4769) email: julie.pullen@nrlmry.navy.mil

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LONG-TERM GOALS

The long-term goal of this effort is to evaluate HYbrid Coordinate Ocean Model (HYCOM) initial and boundary conditions supplied to the air-ocean coupled system represented by the globally-relocatable high-resolution atmospheric model in the Coupled Ocean Atmosphere/Ocean Mesoscale Prediction System (COAMPS®[1]) and the NRL Coastal Ocean Model (NCOM). Related projected outcomes will include improvements to NCOM's treatment of boundary conditions and exploration of the relative sensitivity of coupled model skill to boundary, initial and surface forcing perturbations.

OBJECTIVES

The scientific objectives of this long-term effort are to: (1) to establish the infrastructure for ingestion of HYCOM (global and regional) boundary and initial conditions (BCs and ICs) into globally-relocatable coupled COAMPS/NCOM, (2) quantitatively evaluate HYCOM sources of ICs and BCs against other comparable available sources and provide feedback as to areas for improvement in HYCOM fields, (3) improve NCOM treatment of lateral BCs to best facilitate information exchange across the boundaries, and (4) explore ensemble techniques to quantify the relative impacts of ICs, BCs and surface forcing on the predictive skill of the coupled system for selected coastal regions throughout the world.

APPROACH

Our (Julie Pullen and Paul May, NRL-MRY) technical approach is to work closely with colleagues at NRL-SSC (including John Kindle, Sergio deRada, and Joe Metzger) and the wider NOPP-HYCOM community to acquire HYCOM fields as they become available, to test HYCOM for ICs and BCs, and provide feedback on the HYCOM fields used in this manner. We will make use of diverse data sets in the evaluation process including California Cooperative Ocean Fisheries Investigations (CalCOFI) US West Coast Conductivity, Temperature, and Depth (CTD) data. The infrastructure to ingest different sources of ICs and BCs will be consolidated into the coupled modeling system for transition to other applications. We will also improve the BC treatment in NCOM to use a flow relaxation zone or buffer region to better transition information across the boundary, and apply ensemble ocean techniques (Auclair et al. 2003) to assess the factors that contribute most to forecast uncertainty (ICs, BCs, or surface forcing). Initially our efforts focus on the southern California coastal region, however

[1] COAMPS® is a registered trademark of the Naval Research Laboratory.

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extension to other regional areas of interest will proceed in coordination with upcoming data collection efforts (e.g., ONR's Indonesian Straits DRI).

WORK COMPLETED

From multiple runs of regional, high-resolution, data-assimilating NCOM it is possible to begin to characterize errors in modeling the evolving temperature, salinity, and velocity fields. Regional NCOM simulations from a southern California area, using global NCOM and global HYCOM as initial and boundary conditions, were compared with seasonal CalCOFI CTD data for fall (shown below) and spring 2003 (not shown). The initial conditions from both the global HYCOM and global NCOM models themselves were also evaluated by comparing them to the CalCOFI data.

A set of procedures to access and interpolate global HYCOM and global NCOM fields to regional grids was created and a regional 3-km NCOM nested ocean model was forced at the surface (one-way) with momentum, heat, and moisture fluxes from a 9-km COAMPS run, and at the lateral boundaries by global T,S,U,V fields. The regional Southern California (SoCal) NCOM ocean model runs for 24-hr then assimilates a daily T,S,U,V and surface height analysis from NCODA using an incremental-update procedure. The SoCal NCOM model is nested (one-way) within a HYCOM 1/12 degree (v5.3) experimental global ocean model run by Joe Metzger at NRL-SSC and within the global 1/8 degree NCOM model run operationally at the Naval Oceanographic Office. Boundary conditions are updated at the time period of the globally saved fields--every 24 hours for HYCOM and every six hours for global NCOM. It should be noted that global HYCOM (1/12 degree) is in the early stages of development and does not assimilate data at this point, while global NCOM (1/8 degree) does assimilate data via the Modular Ocean Data Assimilation System (MODAS).

Global HYCOM or global NCOM boundary conditions are applied to the NCOM domain as a one-grid point inflow boundary flux. NCOM also uses a Smagorinski radiation (outgoing) boundary condition. The model was initialized 1-Oct-2003 from global HYCOM surface height, T, S, U, and V fields. Efforts to implement a flow relaxation or blend zone in NCOM (to replace the one-grid point BC) have been established and tested on temperature and salinity. Work is underway to extend the treatment to include velocity fields in the relaxation procedure.

The modeling time frames, October 2003 and April 2003, were chosen to coincide with periodic seasonal CalCOFI hydrographic surveys of the Southern California Bight. The CalCOFI CTD data was not used in the data assimilation and is an ideal high-quality data set for verifying the analysis/forecast temperatures and salinities.

RESULTS

Using global HYCOM ICs and BCs, the mean values of the Forecast minus Observed temperature (Temperature Bias) shows good agreement near the surface, where there is lots of data, but significant warm and cold biases in the thermocline and deeper water (Figure 1). The scatterplot shows similar systematic differences between the forecast temperatures and observed CalCOFI CTD temperatures. There is a near-surface forecast temperature bias of -0.2°C, a +1.5°C warm bias in the seasonal thermocline, and a –0.5°C cold bias in deeper (250 m) water.

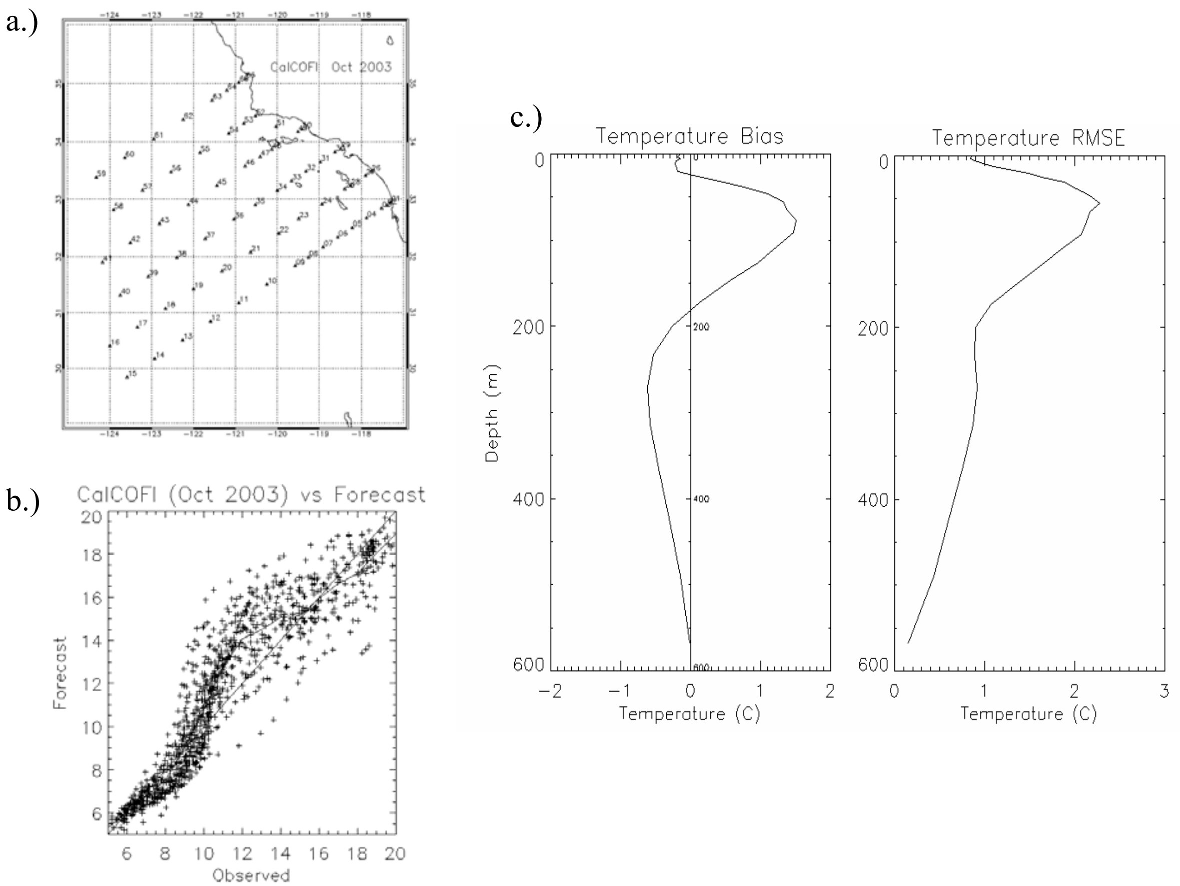

Figure 1: a.) shows the locations of the CalCOFI CTD survey stations occupied during the period of 10 Oct 2003 through 4 Nov 2003. The nested NCOM SoCal domain has its southern-most boundary at 32N and its westernmost boundary at -124W. b.) A scatter-plot of observed vs. forecast temperatures (which are interpolated in space and time to CalCOFI sample locations). c.) temperature bias and rmse for all the profiles that lie within the NCOM SoCal domain.

A cross-section through model and observations (Fig. 2) shows differences in both the strength and position of the thermocline. In particular, modeled or forecast temperature profiles generally have weaker and more diffuse vertical temperature gradients (thermoclines) than the observed profiles.

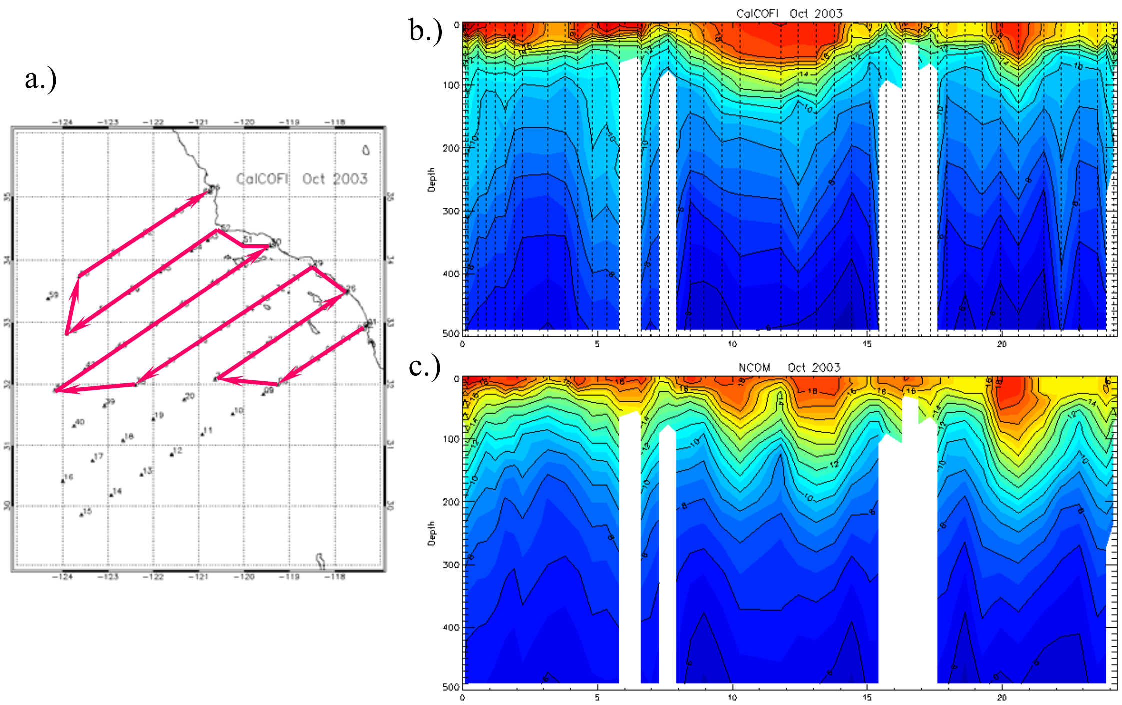

Figure 2. a.) shows the path through CalCOFI CTD stations used to make the temperature cross-section plots. b.) the temperature-depth profile along the indicated path is marked with CalCOFI station locations. c.) is a comparable temperature cross-section from the nested SoCal NCOM model forecasts. Model temperature profiles in this figure are interpolated to match (in space and time) appropriate CalCOFI profiles.

Forecast errors in the regional model, even with data assimilation, are strongly affected by errors in the initial and open boundary conditions. Sub-surface values, where assimilated data is rare (about one observations per week in the SoCal region) will maintain the characteristics of the initial conditions for a longer period of time than the surface temperatures, where there is much satellite data to assimilate.

To investigate the quality of the initial input fields to nested NCOM, bias and RMSE statistics of global HYCOM and global NCOM were computed (but not shown) for October and April 2003 using individual CalCOFI CTD profiles. Not surprisingly, thermocline temperature errors in NCOM initial conditions, which have data assimilation (~1°C), are smaller than errors from HYCOM (~2.5°C), which does not use data assimilation. Also, global HYCOM shows a consistent deep warm bias of 1-2°C in the Southern California region.

Large differences in the T/S relationships are apparent (Fig. 3) between the global sources of initial/boundary conditions and the observations. Moreover, global HYCOM and global NCOM appear to have a similar climatology which may be an artifact of common methods or data used to initialize the global models, or evidence of similar mixing rates in the two global models.

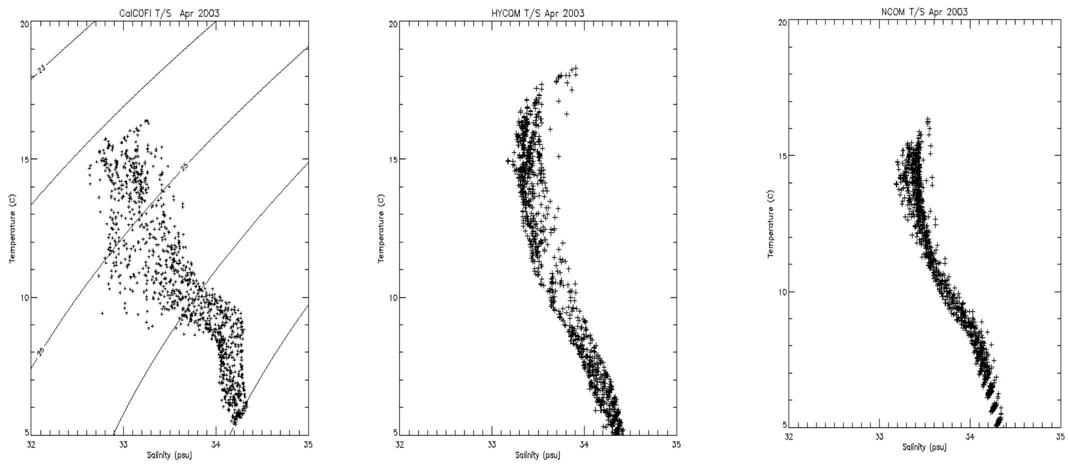

Figure 3: Shown here are the T/S diagrams for April, 2003 of CalCOFI, and global HYCOM and global NCOM forecasts for the same time period and locations as the observations.

IMPACT/APPLICATIONS

The sensitivity of nested model forecasts to the quality of ICs and BCs has been demonstrated. Our results emphasize the importance of utilizing data assimilation in the global models that are used as initial and boundary conditions for nested coastal models. We intend to extend this study to include using data-assimilating global HYCOM fields as soon as they become available.

TRANSITIONS

The capability of using global HYCOM as a source for coupled NCOM ICs and BCs has been built into the set-up procedure for NCOM currently being tested for the Coupled Modeling Initiative Naval Special Warfare RTP.

RELATED PROJECTS

Air-Ocean Coupling in the Coastal Zone [PI: Pullen – NRL Base 6.1] addressing basic research issues related to the identification and understanding the interaction between the ocean and the atmosphere in the littoral region.

Battlespace Environments Institute (BEI) [PI: Hodur – CHSSI 6.3] migrating existing DoD atmosphere, ocean, and space modeling applications to the Earth System Modeling Framework (ESMF) and assisting in transitioning non-DoD ESMF applications to DoD.

Littoral Warfare Team Adaptive Sampling Integration [PI: Bishop - RTP] developing and transitioning the capability to the Naval Oceanographic Office (NAVO) to utilize adaptive sampling to improve predictions of sound speed velocity fields for Anti-Submarine Warfare (ASW)

A Rapidly Relocatable, Coupled, Mesoscale Modeling System for Naval Special Warfare [PI: Allard – RTP] delivering within the COAMPS-OS framework a high-resolution coupled modeling capability to the NSW Mission Support Center.

REFERENCES

Auclair, F., P. Marsaleix, and De Mey, P., 2003. Space-time structure and dynamics of the forecast error in a coastal circulation model of the Gulf of Lions, Dynamics of Atmospheres and Oceans 36, 309–346.